AD NUMBER
ADA800244
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AUTHORITY
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UNCLASSIFIED-AUTH. HDQ. AIR WEATHER SERVICE LTR. DATED 3RD. DEC 1945
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ANALYSIS AND FORECASTING OF TROPICAL CYCLONES OF 1944 IN THE CARIBBEAN SEA AND WESTERN ATLANTIC OCEAN, WITH THE AID OF AIRCRAFT RECONNAISSANCE REPORTS AND RAWINS

AWS Tech. Rept. 105-15
~~9230-TR105.15~~

PUBLICATIONS OF THE WEATHER DIVISION
HEADQUARTERS ARMY AIR FORCES

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from an analysis of surface and upper air data can be resolved into two factors: (a) detecting the existence of tropical cyclones which form east of the Lesser Antilles, before entering the observational network, and (b) forecasting the formation of tropical storms in the western Atlantic, Caribbean and Gulf of Mexico. Although the dynamics of hurricane formation is still in the purely hypothetical state, there are certain synoptic conditions with which the formation of tropical storms may be directly associated.

Many tropical cyclones form on easterly waves. The probability of formation in this manner is believed to be greater when an upper-level trough in the westerlies at higher latitudes moves north of the wave in the easterlies. Exactly what conditions are necessary for storm development on an easterly wave is not known, nor is it known why troughs in the middle-latitude westerlies affect this development. One suggestion is that the westerly trough causes slight cyclonic curvature of the wind flow in the easterlies south of the trough, increasing the amount of convergence in the vicinity of the easterly wave when the two become coincident.

Another synoptic situation leading to the formation of tropical storms in the western Caribbean is in the so-called "triple-point" where a north-south col or westerly trough joins the intertropic convergence zone north of Panama. Using upper-air streamline and pressure analysis, somewhat as Deppermann did with surface reports,[1] it was possible to forecast the development of tropical cyclones in the equatorial trough north of Panama as much as three days in advance of their actual formation.

Five of the eleven tropical cyclones in 1944 shown in Figure 1 entered the western Atlantic or Caribbean as closed centers from somewhere east of the Lesser Antilles, and were of unknown origin (storm tracks number 3, 5, 7, 8, 10); three formed on easterly waves (storm tracks number 2, 4, 6); and three formed in the "triple-point" north of Panama (storm tracks number 1, 9, 11).

DETECTING THE EXISTENCE OF TROPICAL CYCLONES

Dunn's empirical rules[2] were valuable in detecting the existence of tropical cyclones wyich entered the observational network as closed centers. During the 1944 hurricane season, upper-wind observations from

FIG. 1

land stations and aircraft and twenty-four hour pressure changes provided the earliest indications of the existence of tropical storms. Observations of other meteorological elements affected by tropical cyclones merely served to confirm these earlier indications. Since none of these tropical cyclones had reached maturity prior to entering the observational network, the conclusions derived from this season's hurricane forecasting cannot be applied to mature hurricanes.

The early stages in the development of the Atlantic Hurricane of September provides a good example of the analysis used in detecting the existence of tropical cyclones which enter the Caribbean observational network as closed centers.

Streamline charts of the 7,000-ft winds aloft and aircraft reconnaissance reports used in this analysis are shown in Figures 2 to 6. In order to demonstrate the sensitivity of twenty-four hour surface pressure changes in detecting tropical disturbances of this type, these values were included in the diagrams. The 7,000-ft winds were used for this analysis in order to eliminate the effect of topography on the true streamline patterns, and because it is believed that a closed circulation occurs between 7,000 and 10,000 ft before taking place in higher or lower levels during the early stages of hurricane development. The heavy solid line in the diagrams shows the position of the easterly wave south of the closed center.

The first indications of the existence of a tropical disturbance east of the Lesser Antilles were found on a routine weather reconnaissance flight by the Army Hurricane Reconnaissance Unit on 7 September. The 071830Z synoptic surface chart of the area showed nothing abnormal. An easterly wave approaching the Lesser Antilles was suspected from the northeasterly winds aloft reported at St. Lucia and Barbados and from the southeasterly wind flow at Paramaribo and Cayenne. The only real clues to the possible existence of a tropical disturbance were found in the southwest winds and altostratus and cirrostratus overcast with light, continuous rain reported by the aircraft.

By 081000Z, the winds at St. Lucia and Barbados backed to northwest and further confirmed the previous suspicions. Twenty-four hour surface pressure changes of two millibars, reported at that time, were not con-

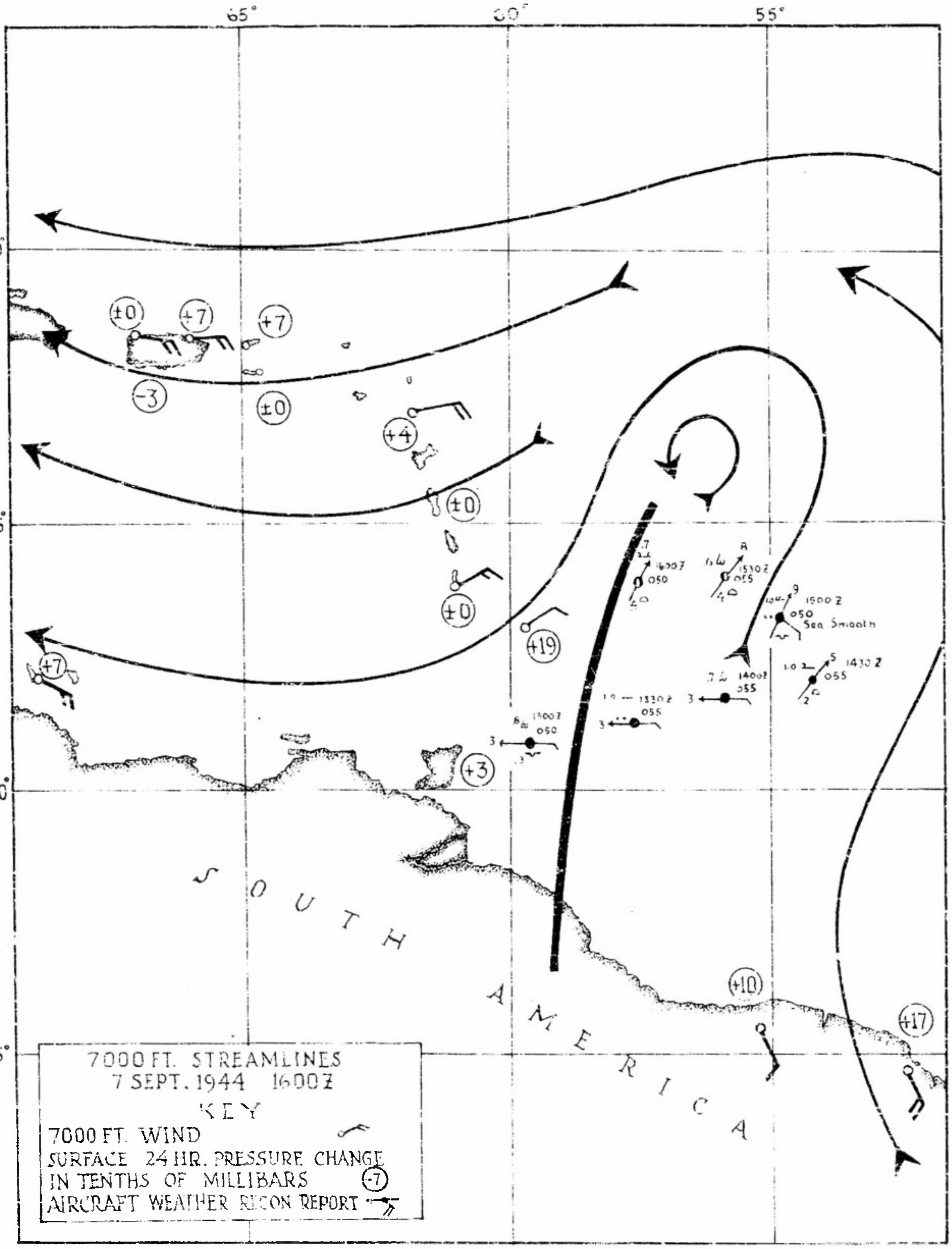
65°
60°
55°
20°
15°
10°
5°
SOUTH AMERICA
7000 FT. STREAMLINES
7 SEPT. 1944 1600Z
KEY
7000 FT. WIND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS
AIRCRAFT WEATHER RECON REPORT
Sea Smooth

FIG. 2

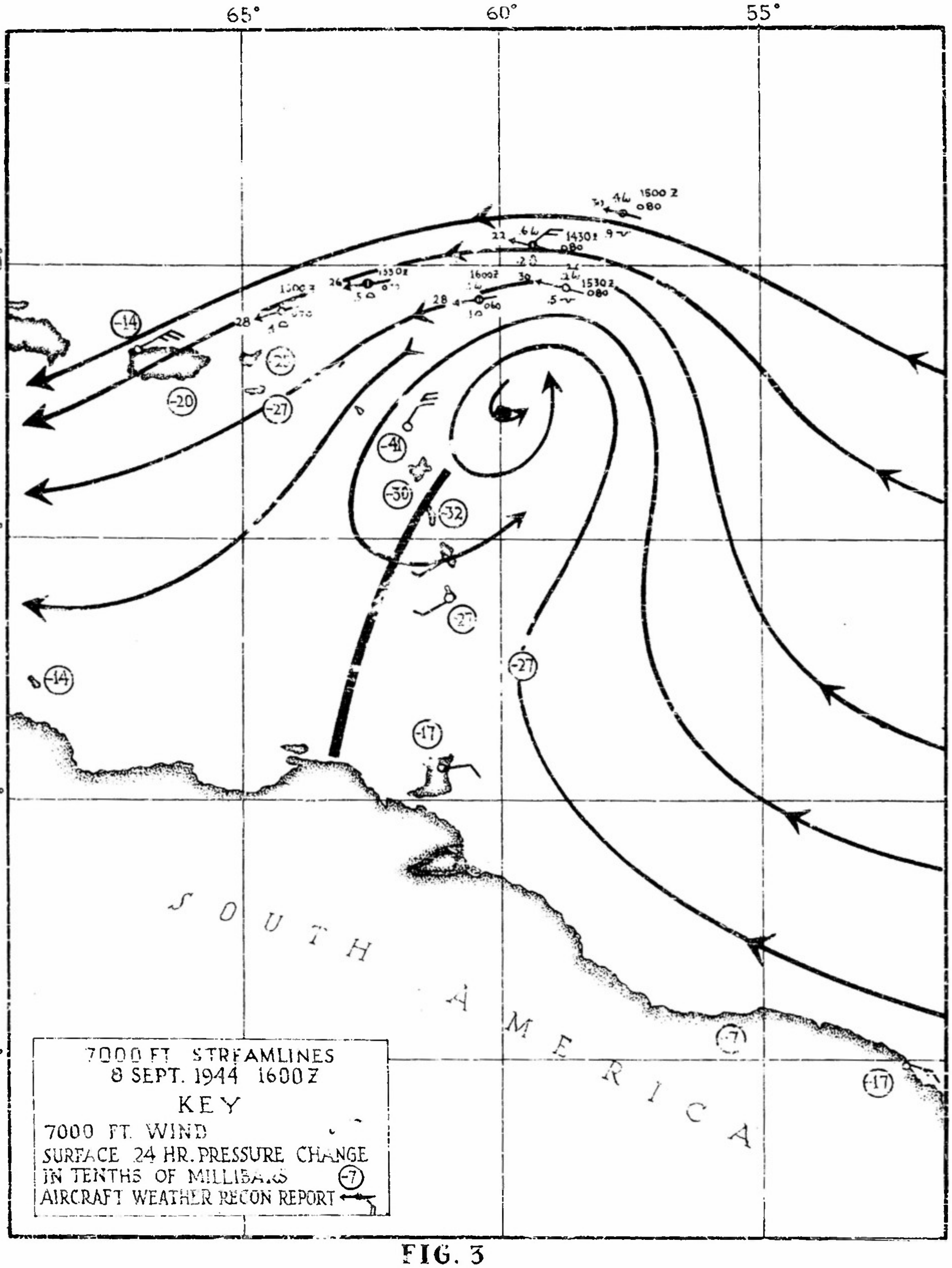
65°
60°
55°
20°
15°
10°
5°
SOUTH AMERICA
7000 FT. STREAMLINES
8 SEPT. 1944 1600Z
KEY
7000 FT. WIND
SURFACE 24 HR. PRESSURE CHANGE IN TENTHS OF MILLIBARS
AIRCRAFT WEATHER RECON REPORT

FIG. 3

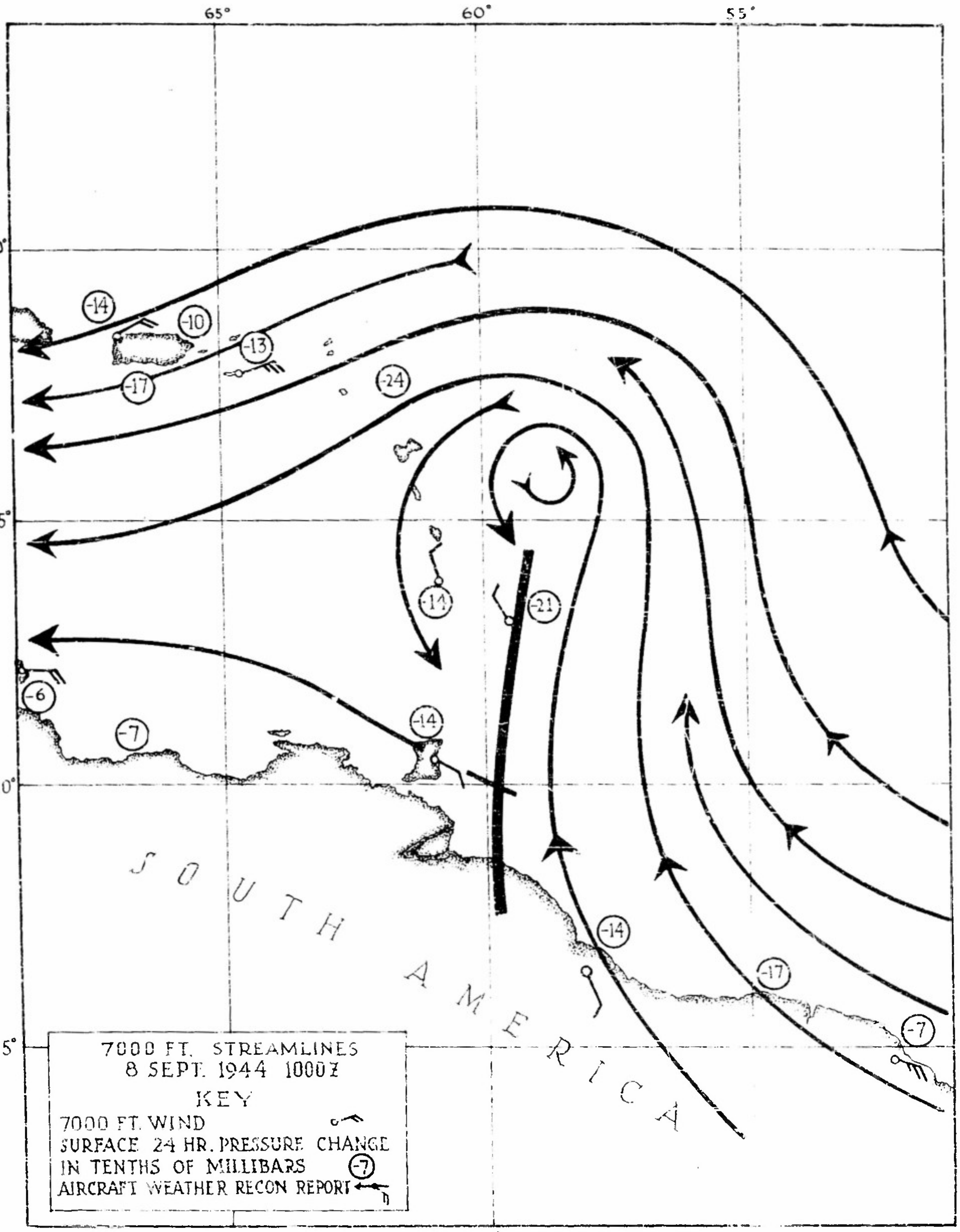
65°
60°
55°
20°
15°
10°
5°
SOUTH AMERICA
7000 FT. STREAMLINES
8 SEPT. 1944 1000Z
KEY
7000 FT. WIND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS
AIRCRAFT WEATHER RECON REPORT
-14
-10
-13
-17
-24
-14
-21
-6
-7
-14
-14
-17
-7

FIG. 4

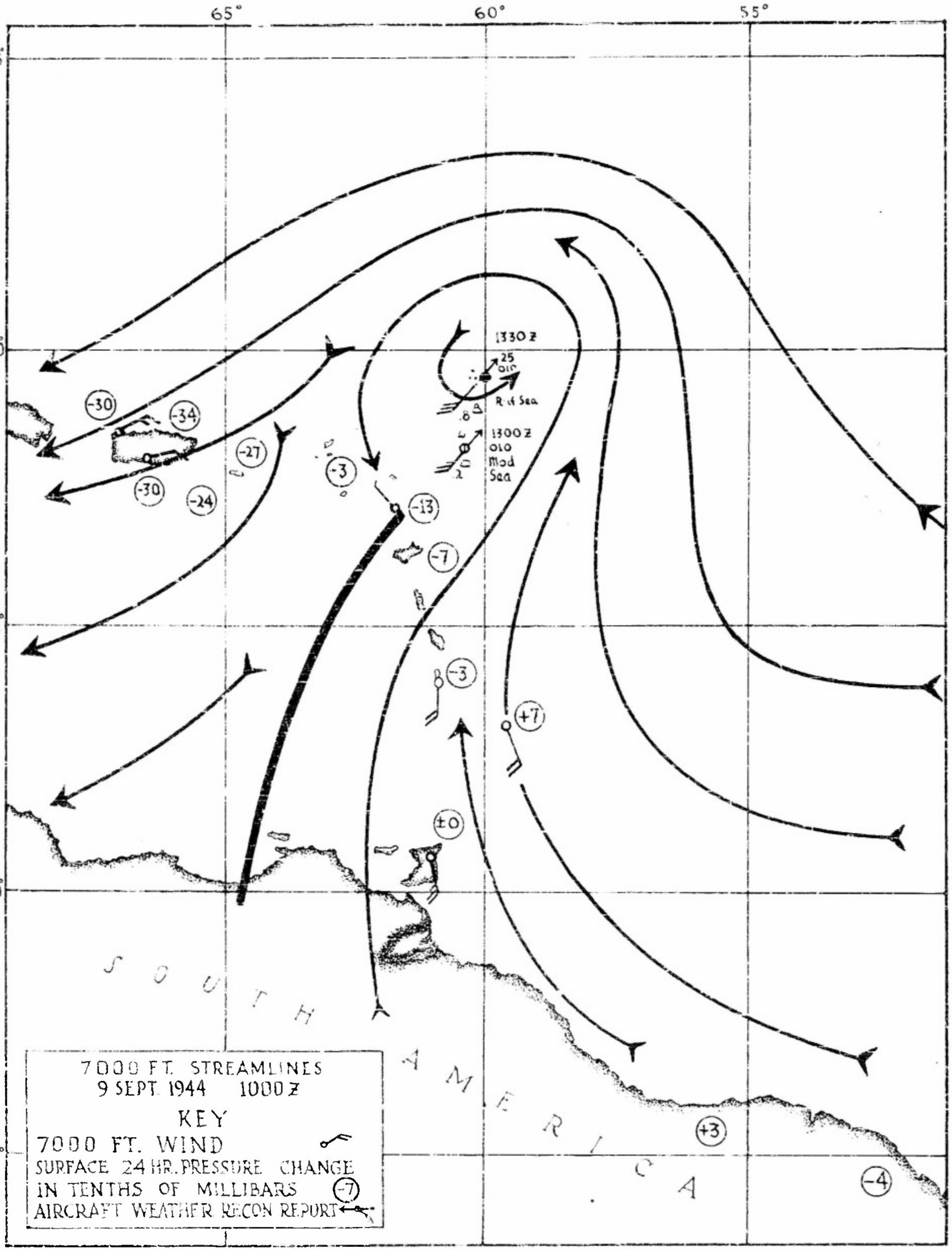
65°
60°
55°
25°
20°
15°
10°
5°
1330 Z
25
010
R of Sea
1300 Z
010
Mod
Sea
(-30)
(-34)
(-27)
(-3)
(-30)
(-24)
(-13)
(-7)
(-3)
(+7)
(±0)
(+3)
(-4)
SOUTH AMERICA
7000 FT. STREAMLINES
9 SEPT. 1944 1000 Z
KEY
7000 FT. WIND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS (-7)
AIRCRAFT WEATHER RECON REPORT

FIG. 5

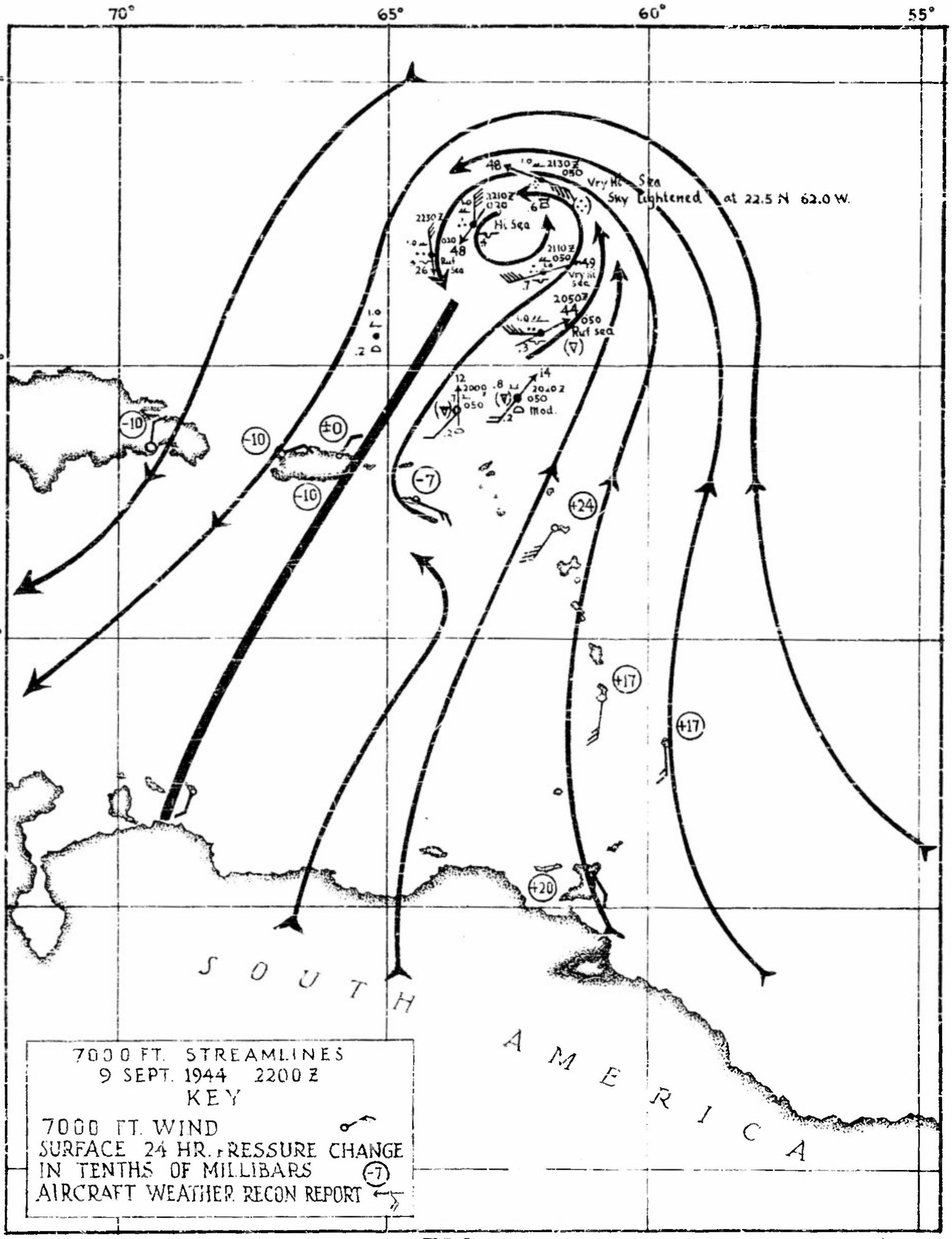
70°
65°
60°
55°
25°
20°
15°
10°
5°
Vry Hi Sea
Sky Lightened at 22.5 N 62.0 W.
Hi Sea
Ruf sea
Mod.
S O U T H
A M E R I C A
7000 FT. STREAMLINES
9 SEPT. 1944 2200 Z
KEY
7000 FT. WIND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS
AIRCRAFT WEATHER RECON REPORT

FIG. 6

sidered to be a strong indication of the existence of a disturbance, since pressure falls of that magnitude may precede easterly waves which do not subsequently deepen. Significant pressure falls of four millibars were reported from Antigua at 081600Z, and a closed circulation was shown in the 7,000-ft. streamline pattern. As the disturbance moved northwest of Antigua, reports from the island stations became less significant. Not until 091300Z when weather observations from a Navy reconnaissance aircraft were made could an approximate fix be obtained. At 092230Z, the existence of a dangerous storm was confirmed by an Army reconnaissance mission when observations on this flight completely encircling the storm showed winds to 49 knots at flight altitude and force nine surface winds. It is of interest to note that on this flight, heavy rain and cumulonimbus clouds were only found in the northeast sector of the storm, while clouds in other quadrants consisted of many stratiform layers.

EASTERLY-WAVE TYPE STORMS

A critical forecasting problem is presented by tropical cyclones which form on easterly waves in the Gulf of Mexico and in the Atlantic Ocean near the Bahama Islands. Those areas of formation are near the Continental United States, and early detection is necessary to provide adequate warnings. Since little is known about the circumstances under which this formation occurs, all easterly waves were treated as areas of possible storm development.

Streamline analyses and time cross-sections of selected stations were used to determine the existence, movement and changes in intensity of easterly waves. Normally, the easterly wave was first detected approaching the Lesser Antilles from the 3,000 to 12,000-ft winds aloft, which backed to a northeasterly direction in advance of the wave and veered to southeast after its passage. There were, however, instances where the windshift which occurred was from east to southeast and the approaching wave could not be readily detected. Time cross-sections were useful in the analysis of this tyle of wave, since slight wind shifts at a given station are readily discernible on this chart.

The hurricane which affected Wilmington, N. C., on the evening of 1 August 1944, formed on an easterly wave over the Atlantic near the Bahamas. Streamline charts of the 7,000-ft winds, showing this development,

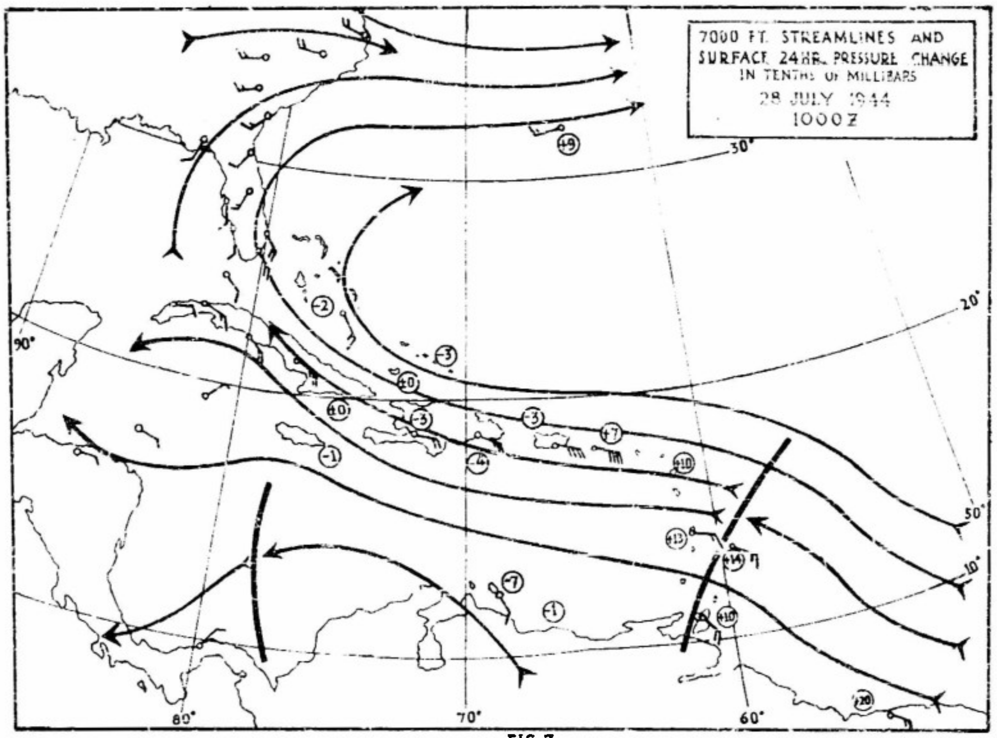
7000 FT. STREAMLINES AND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS
28 JULY 1944
1000 Z
30°
20°
10°
90°
50°
80°
70°
60°

FIG. 7

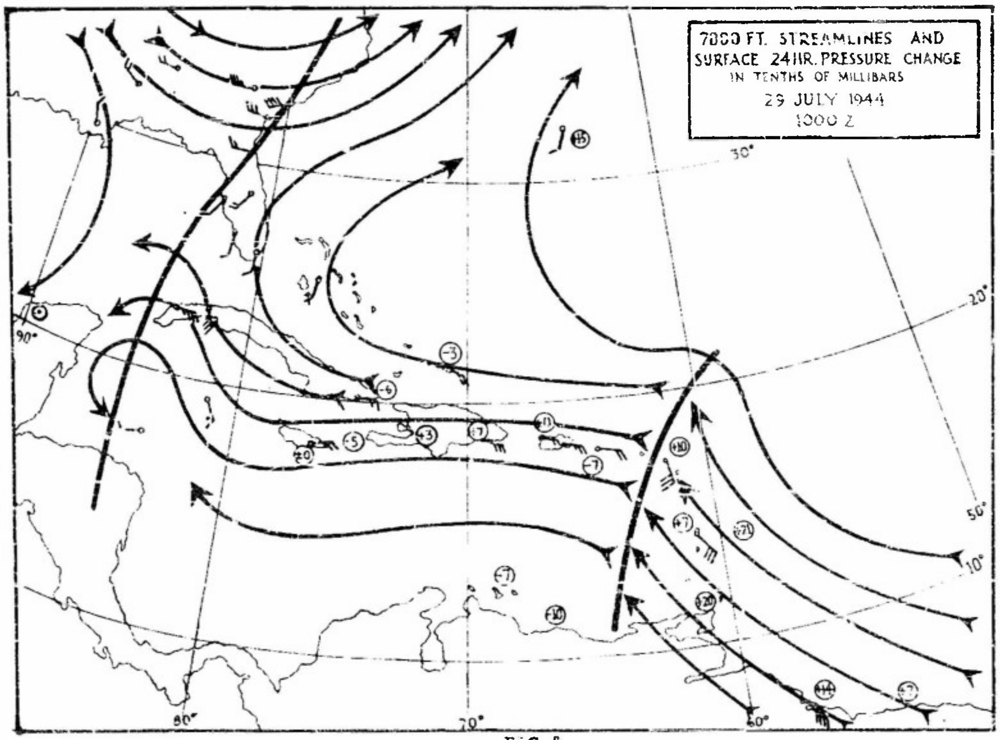
7000 FT. STREAMLINES AND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS
29 JULY 1944
1000 Z
30°
20°
10°
90°
50°
80°
70°
60°

FIG. 8

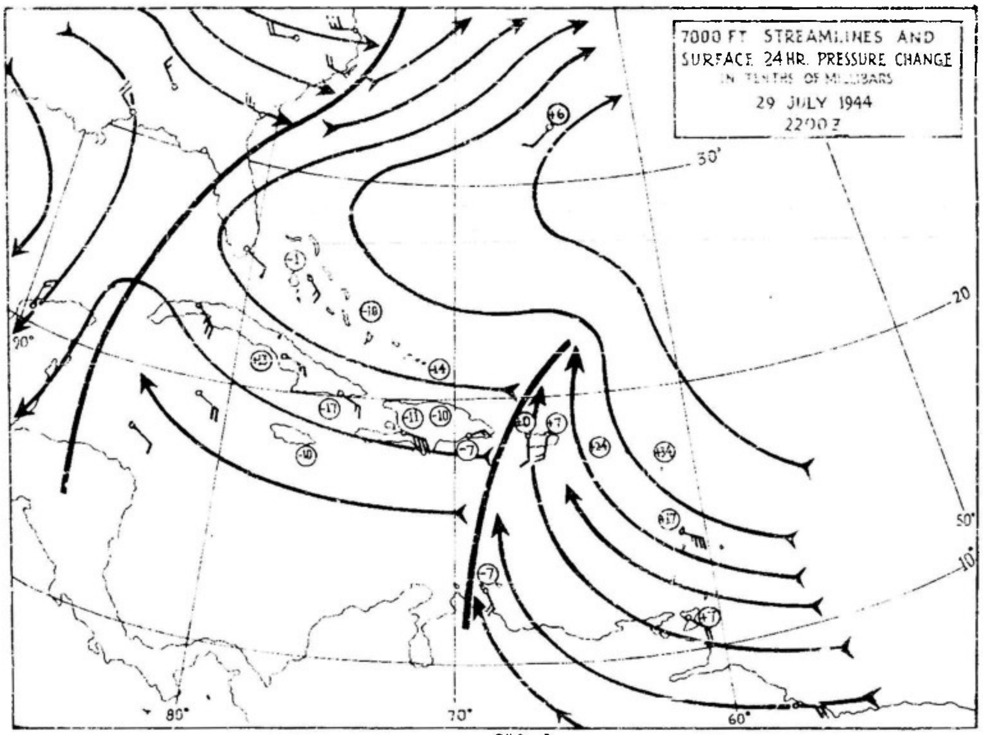
7000 FT. STREAMLINES AND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS
29 JULY 1944
2200 Z
30°
20
50°
10°
80°
70°
60°

FIG. 9

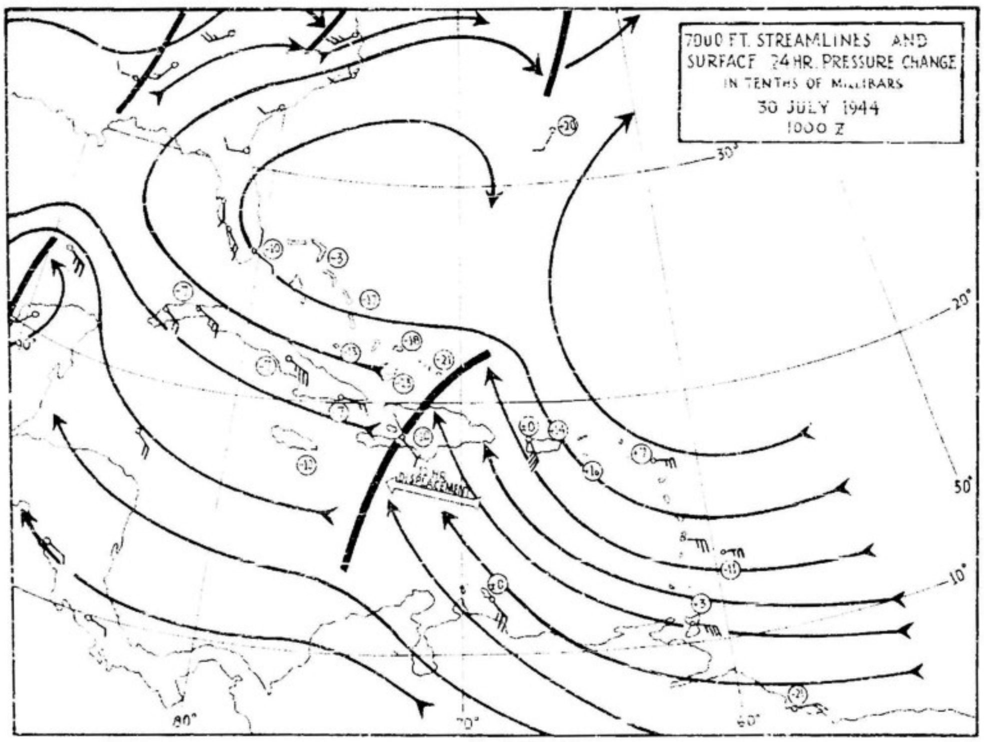
7000 FT. STREAMLINES AND
SURFACE 24 HR. PRESSURE CHANGE
IN TENTHS OF MILLIBARS
30 JULY 1944
1000 Z
30°
20°
50°
10°
80°
70°
60°
DISPLACEMENT

FIG. 10

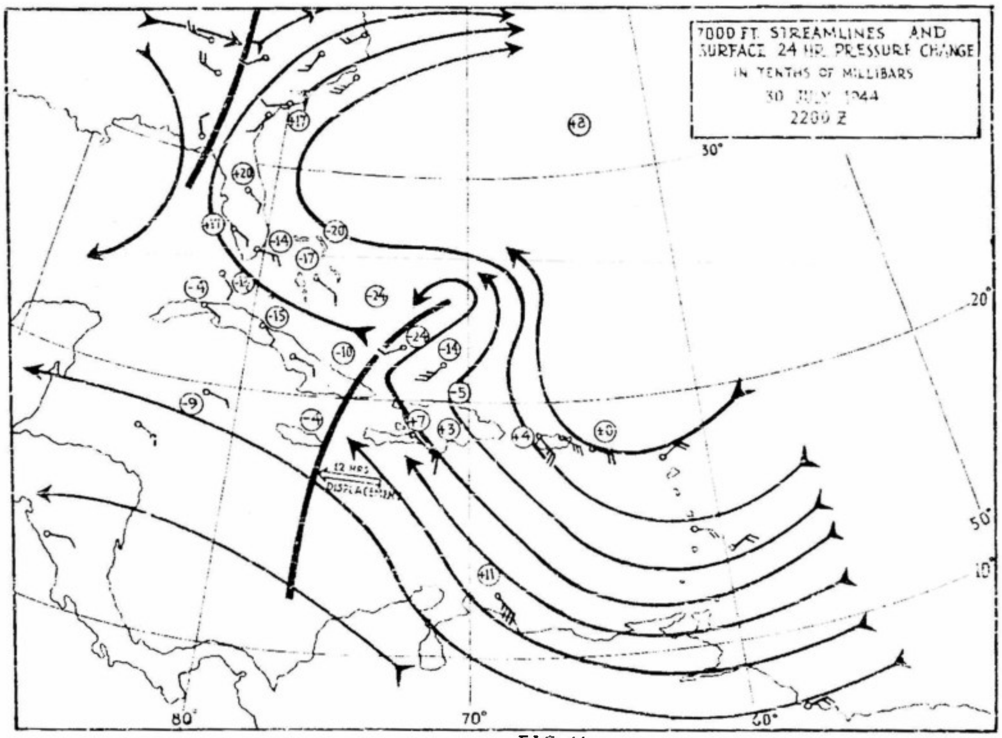
7000 FT. STREAMLINES AND SURFACE 24 HR. PRESSURE CHANGE IN TENTHS OF MILLIBARS
30 JULY 1944
2200 Z
12 HRS. DISPLACEMENT
30°
20°
10°
50°
80°
70°
60°

FIG. 11

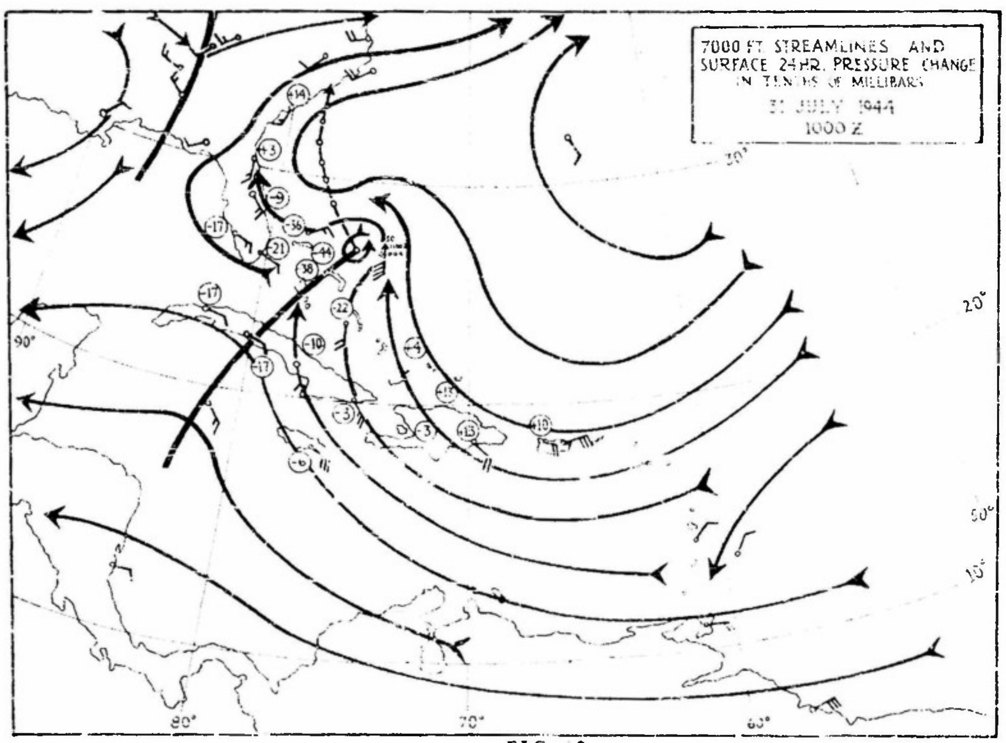
7000 FT. STREAMLINES AND SURFACE 24 HR. PRESSURE CHANGE IN TENTHS OF MILLIBARS
31 JULY 1944
1000 Z
20°
10°
50°
90°
80°
70°
60°

FIG. 12

are illustrated in Figures 7 to 12. Twenty-four hour pressure changes are included to show the indications of the easterly wave and its subsequent development in these pressure changes. Extrapolation of a wave in the westerlies traveling across the northern United States brought it to a position coinciding with that of the easterly wave at about the time of formation of this storm. The effect of a westerly trough on the development of easterly waves is still open to question; however, a similar trough passage occurred during the formation of the tropical storm of 14 July 1944, near the Bahamas. This strongly suggests that in the polar westerlies are a factor in the intensification and development of easterly waves.

The easterly wave on which the Wilmington Hurricane formed was first detected on the 281000Z streamline charts when the Trinidad winds aloft veered from 100 to 150 degrees after the wave passage. At 291000Z, a well-defined wind shear accompanied by large twenty-four hour pressure rises was noted behind easterly wave. This surge in the easterly air flow can be explained as being due to the intensification of the Azores High, rotation of the axis of this anticyclone, or a combination of both factors.

The easterly wave moved rapidly through the Caribbean at 25 to 30 MPH until it passed just east of Port Au Prince, Haiti, when its velocity decreased to 15 to 18 MPH. Deepening of the wave and development of a cyclonic circulation were evidenced by the southwest winds aloft at Turks and Mayaguana Islands, and by the increasing twenty-four hour pressure falls around the northern portion of this easterly wave. It is significant to note that this development occurred after a deceleration in the westward movement of the wave. At 311100Z a Navy aircraft reconnaissance flight reported winds to 50 knots at 400 ft and force nine surface winds, confirming the existence of a tropical storm. Twenty-four hour pressure falls of 3.5 to 5.0 millibars in the northern Bahamas at 311230Z gave further evidence that this development had taken place. After that time, pilot reports provided the only data for locating the position of this storm unitl at affected the North Carolina coast in the late afternoon of 1 August. Maximum gusts to 80 MPH were reported from the Coast Guard Station at Wilmington as the hurricane moved on shore.

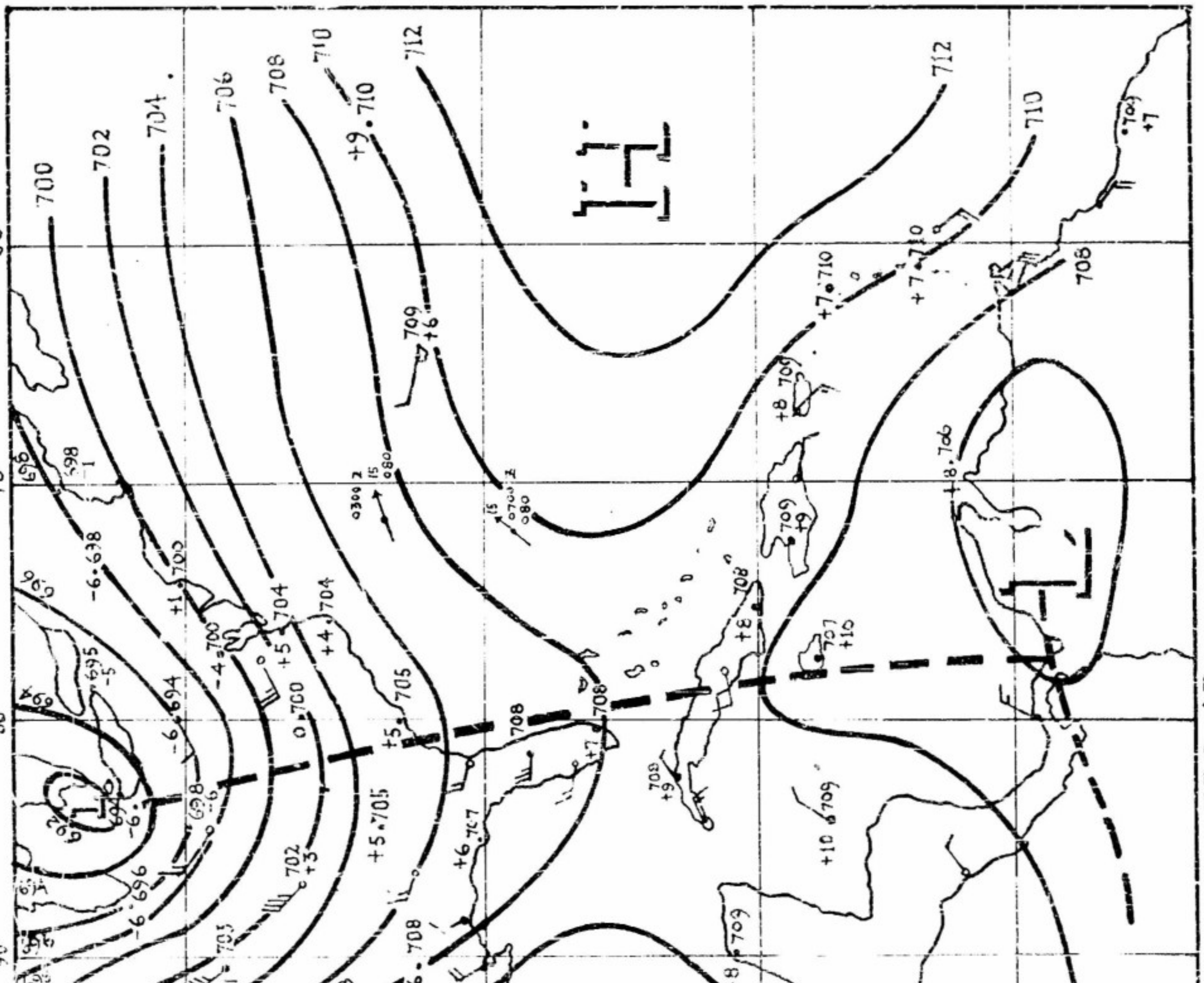
10000 FT. PRESSURE CHART
0400 Z
9 OCT. 1944
Station Model : TT • PPP

FIG. 13

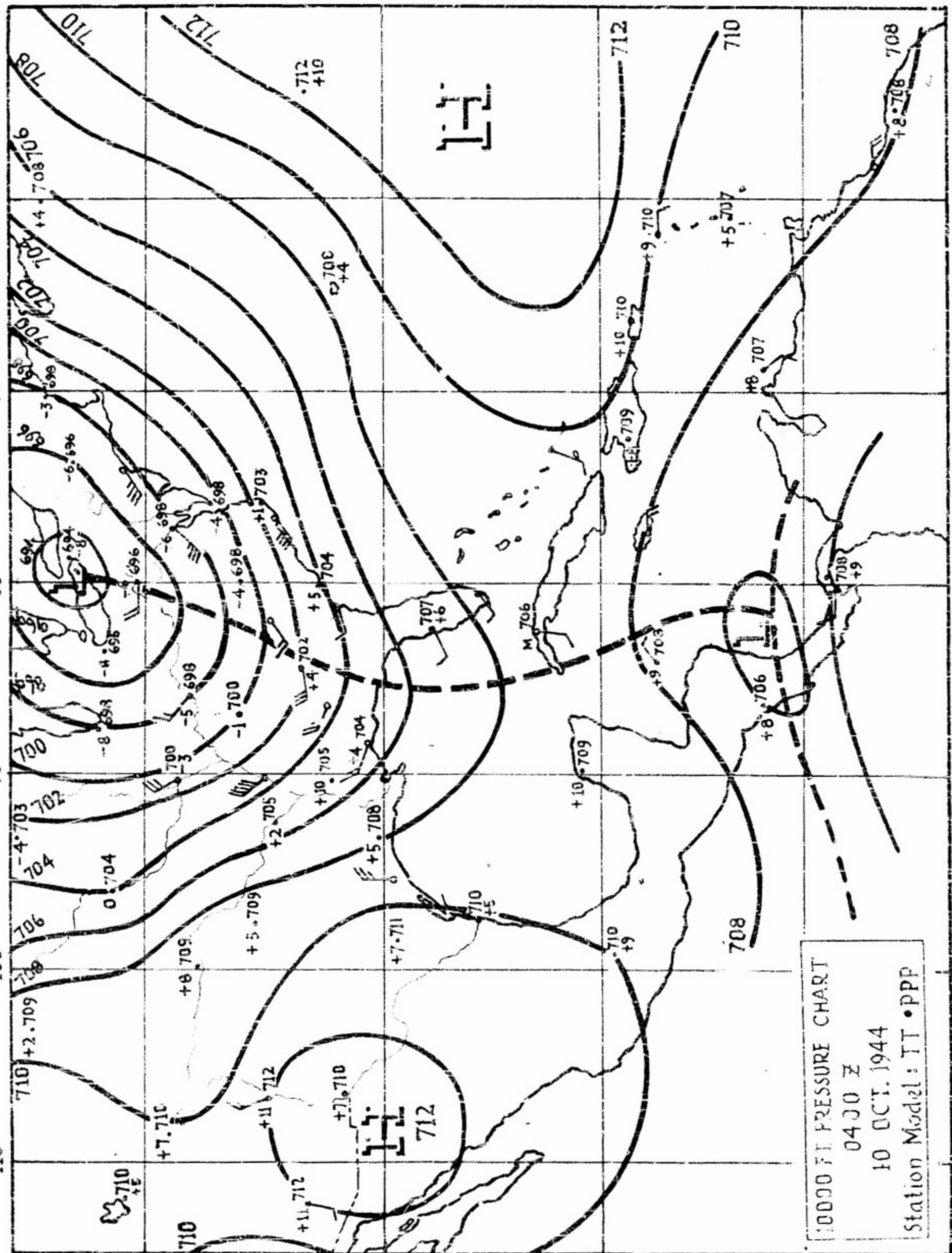
10000 FT PRESSURE CHART
0430 Z
10 OCT. 1944
Station Model: TT •PPP

FIG. 14

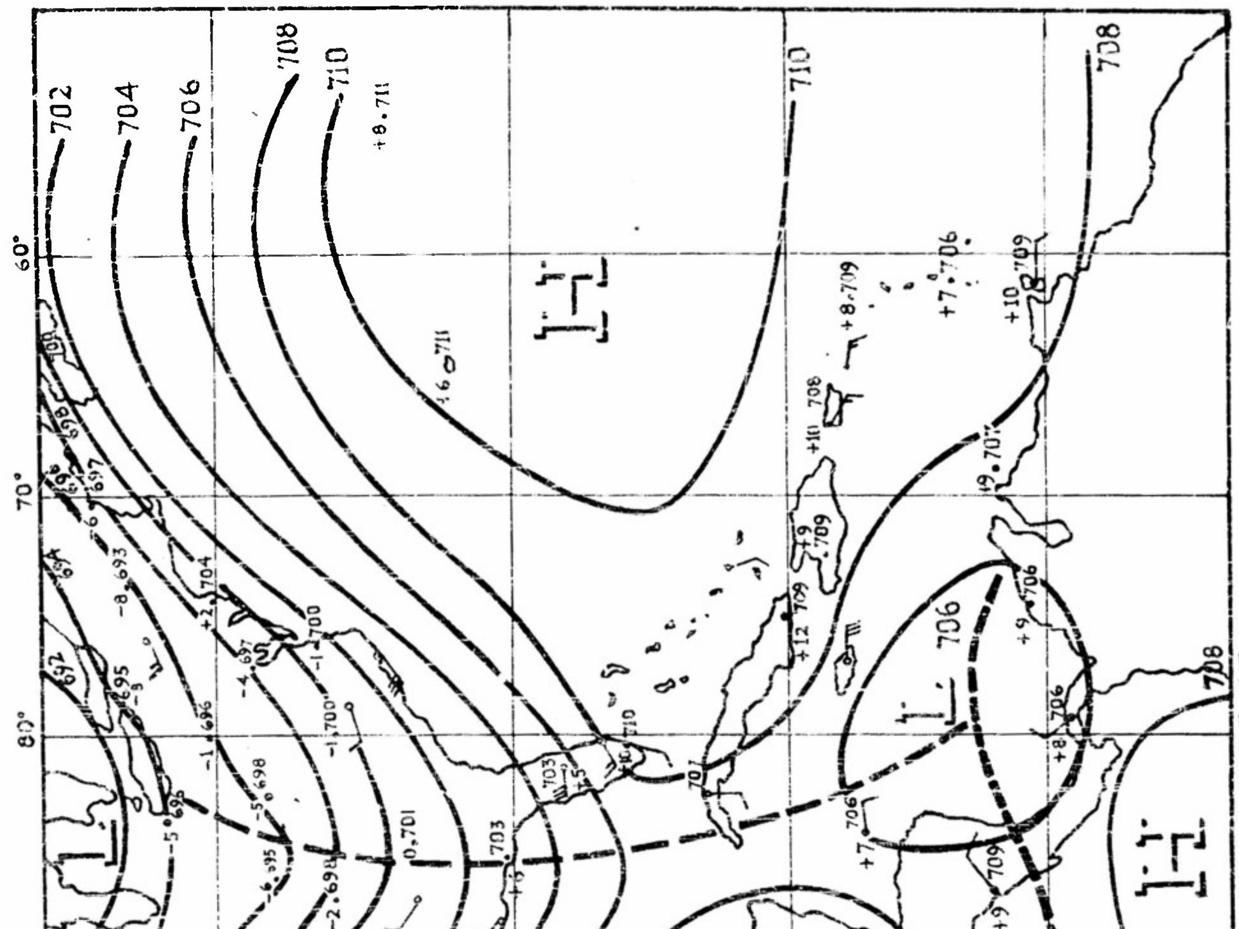
10000 FT. PRESSURE CHART
0400 Z
11 OCT. 1944
Station Model: TT •PPP

FIG. 15

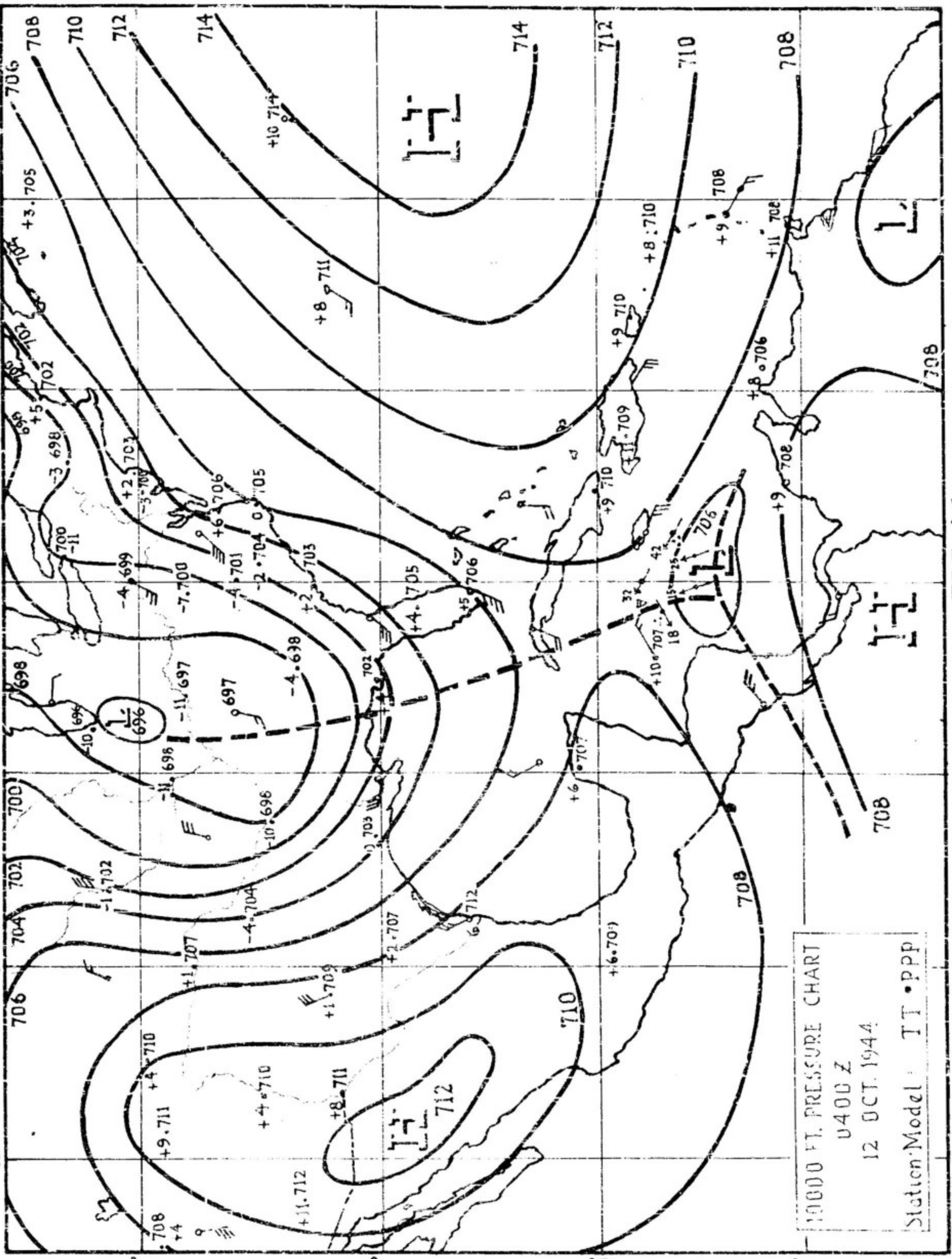
10000 FT. PRESSURE CHART
0400 Z
12 OCT. 1944
Station Model: TT •PPP

FIG. 16

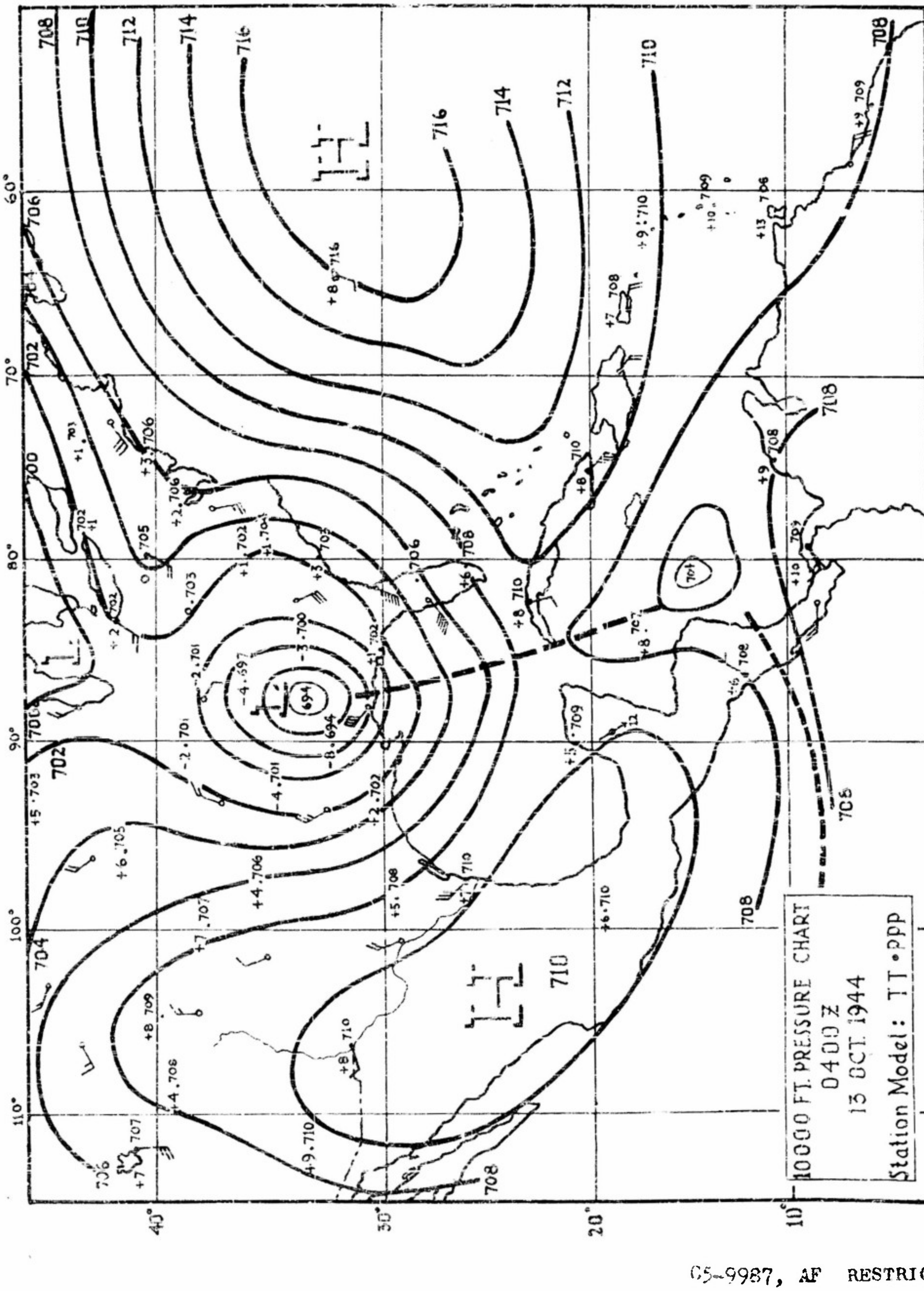
10000 FT. PRESSURE CHART
0400 Z
13 OCT. 1944
Station Model: TT·PPP

FIG.17

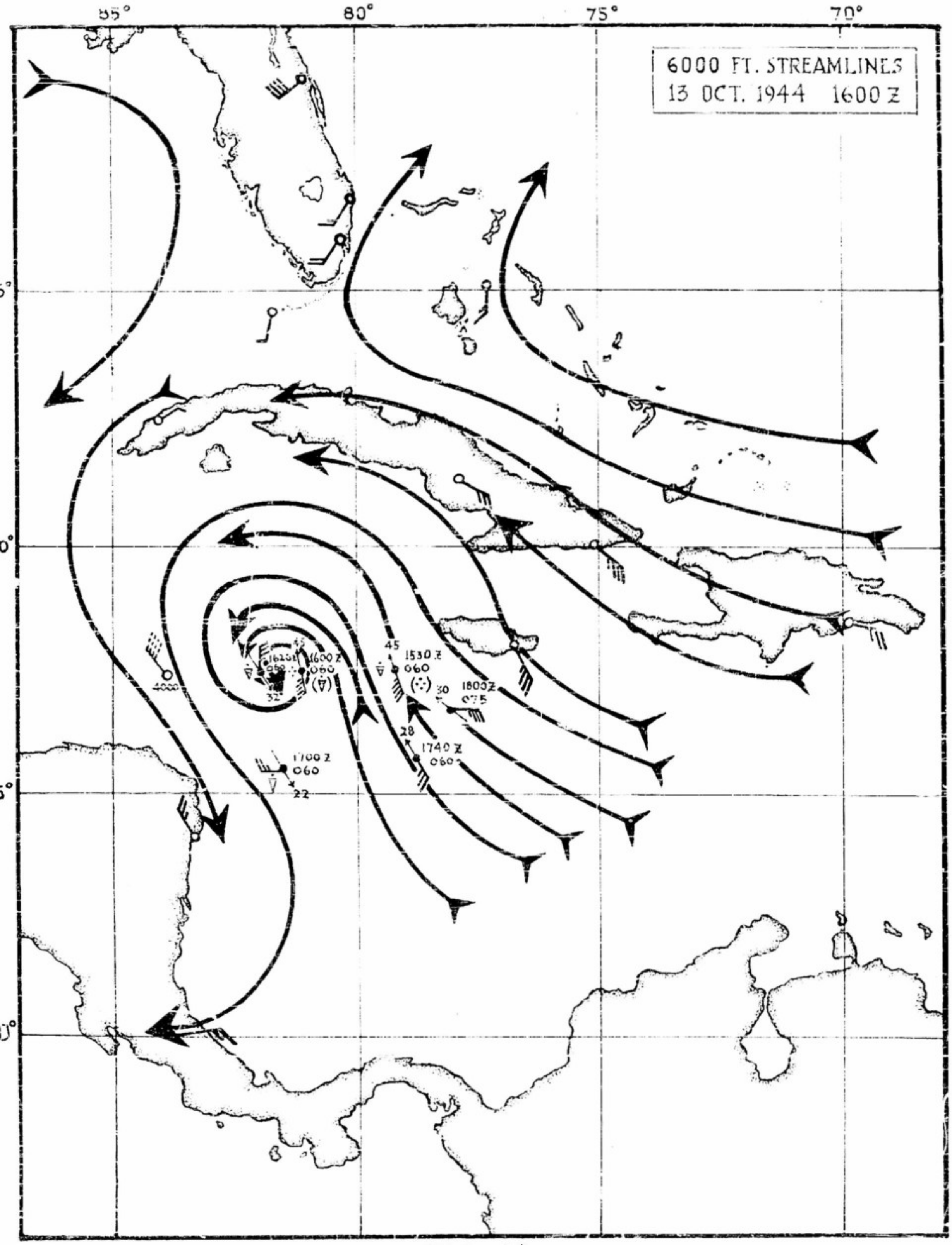

FIG. 18

STORMS FORMING AT INTERSECTION OF INTERTROPIC AND WESTERLY TROUGHS

Forecasting the formation of tropical cyclones in the intertropic convergence zone in the western Caribbean was based to a large extent on the 10,000-ft pressure pattern. The area included in the analysis of 10,000-ft pressure charts was not restricted to the tropics, but included also the United States and western north Atlantic in order to determine the orientation and movement of the large scale, upper-level pressure systems in the temperate latitudes. These systems, which derive the major part of the energy for their maintenance and movement from existing temperature gradients, exert a definite influence on the air flow and associated weather systems, in the tropics, where such temperature gradients are relatively weak or entirely absent. Therefore, an analysis of tropical weather must take into consideration the influence of any middle-latitude atmospheric processes which are responsible for the existence of tropical weather systems. Good confirmation of this concept was found in the 10,000-ft pressure analysis during the formation of the Florida Hurricane of October 1944, shown in Figures 13 to 17.

Isobars, in this analysis, were drawn for two millibar intervals of pressure, with most emphasis placed on the wind flow when drawing for the pressures in the tropics. Despite the relatively weak pressure gradients and the fact that the geostrophic wind equation becomes less valid in tropical latitudes, the effect of large-scale middle-latitude pressure systems on tropical isobaric configurations is quite evident on these charts.

The intertropic convergence zone was placed south of Panama on the basis of the northeast flow at Albrook Field, C. Z., on the 090400Z chart. Further evidence for this position of the front was found on surface charts and from pilot reports. At that time a very deep, cold low was centered over Lake Erie with the westerly trough extending south of this low, lying just east of the Florida Peninsula and projecting southward to a position just east of Panama. Little change in intensity of the low occurred in the next twenty-four hours, and the trough, associated with this low, retrograded to a position directly north of Panama at 100400Z. Northward movement of the intertropic convergence zone into this trough north of Panama was evidenced by the west winds at the Canal Zone, and confirmed by pilot reports on the Miami-Albrook Route, leading to the junction of the intertropic convergence zone and westerly trough. The cold low in the United States with its associated trough remained almost stationary and deepened during the next 72 hours, causing dynamic intensification of the Bermuda High. This intensification of the Bermuda High reinforced the easterly flow through the Caribbean, resulting in increased wind velocities in the northeast sector of the "triple-point" region by 120400Z. (It is not known whether this intensification of the wind flow is a significant factor in the development of cyclones, but it has been noted that a similar increase in wind velocity occurred prior to the formation of several hurricanes during this year). Aircraft reconnaissance of the suspected area showed no evidence of a tropical storm until 131630Z, when wind velocities around a small tropical cyclone were reported up to 45 knots. Figure 18 shows the streamline pattern drawn for winds reported on this flight.

Observations in two other cyclones in the intertropic convergence zone, those of 13 June and 16 September, 1944, afford additional evidence of the pressure and streamline patterns during formation of such storms. The first phase of the development occurs when a deep trough in the westerlies becomes almost stationary and extends well into the tropics. The temperature gradient does not necessarily continue as far south as the intertropic convergence zone. A trough is induced in the easterly flow south of the latitude where a temperature gradient ceases to exist, and the polar-trough line appears to continue well into the low latitudes. If this trough remains stationary west of 75^{o} W. for several days the intertropic convergence zone is forced northward into the area of low pressure by the flow of air from the South Pacific High, and a "triple-point" junction of troughs is formed. Movement of the convergence zone to a position north of Panama into the western Carribbean is usually indicated by westerly winds aloft at Panama, and is first observed by a streamline analysis of the area.

In the Western Hemisphere the intersection of westerly troughs with the intertropic trough is limited to the area of the eastern Pacific Ocean and the Caribbean Sea west of 75^{o} longitude. This is confirmed by Mitchell[3], in his study of tropical cyclones in the western Atlantic and Caribbean from 1886 to 1923. He states that records show no cyclones originate in the Caribbean Sea east of 75° longitude. Tropical cyclones may possibly originate on easterly waves in the Caribbean, but this type of formation usually takes place on the northern end of easterly waves which extend north of the Greater Antilles in the western Atlantic. The reason why this type of storm does not form east of 75° longitude, along the north coast of South America obviously lies in the fact that an intertropic convergence zone does not exist in that area, the inter-tropical trough being far south in the interior of South America.

USE OF RAWINS TO FIND THE STEERING LEVEL

A limitation in the use of the 10,000-ft pressure and stream-line chart for forecasting the movement of tropical cyclones is the extent to which the streamflow at that level is indicative of the actual steering current. There is limited evidence leading to the conclusion that steering of tropical cyclones occurs at the level above the closed circulation. This principle has been applied in forecasting the movement of extratropical cyclones, and during the 1944 hurricane season was also used in forecasting the movement of tropical hurricanes. No definite information is available on the heights to which the circulation of hurricanes extend during various stages of their maturity, but the indications are that the circulation begins in the lower troposphere between 7,000 and 10,000 ft, and builds downward to the surface and upward to as high as 35,000 ft or more as it attains maturity. This would explain why the 10,000-ft streamlines give better results in forecasting tropical cyclones in the formative and immature stages than in the mature and decaying stages. In many instances, especially in low-index situations which are characterized by warm highs and cold lows, the 10,000-ft isobars are a good indication of the air flow at higher levels, but when the steering current is above 20,000 ft, as is the case in mature hurricanes, this level does not yield satisfactory results.

The RAWIN reports from San Juan for 10 September 1944, are shown in Table 1 below:-

Table 1.

	101500Z Sept.		102100Z Sept.	061500Z Sept.
5,000 ft.	220° 17		200° 15	110° 23
10,000 ft.	200° 15		200° 26	080° 26
15,000 ft.	210° 27		230° 19	60° 16
20,000 ft.	230° 13		210° 12	80° 18
25,000 ft.	230° 19		210° 16	60° 18
30,000 ft.	220° 05		200° 14	270° 02
35,000 ft.	200° 18		210° 21	140° 05
40,000 ft.	130° 12	steering level	140° 12	160° 07
45,000 ft.	80° 34			180° 03

An inspection of the San Juan RAWIN observation shown in Table 1, made on 10 September 1944, when the Atlantic Hurricane was located about 250 miles north of Puerto Rico, reveals that the circulation of this hurricane reached 35,000 ft. The height to which the westerly wind component extended can be considered as the height of the circulation. From 101280Z to 110030Z the hurricane, which was of very large diameter, was moving from 120 degrees (west northwestward) at 12 to 14 MPH. If the steering level is considered to be above the level of the cyclonic circulation, the winds between 35,000 and 40,000 ft should have indicated the direction and velocity of movement of the storm. This was verified by the 40,000 ft wind at San Juan which was reported to be 130 degrees 12 MPH at 101500Z. At 102100Z the 40,000-ft wind veered to 140 degrees, which was in close agreement with the northwestward movement of the hurricane between 101830Z and 111130Z shown in Figure 1, storm track number 7. By 111500Z the storm was located more than 500 miles from San Juan, and at that distance the San Juan winds could not be used to determine the steering current. Normal winds for September are shown by the 1500Z RAWIN at San Juan on 6 September 1944 for comparison with those influenced by the storm circulation.

30,000 to 40,000 ft winds along the Atlantic coast of the United States were used to forecast a north-northeastward movement of the Atlantic hurricane along the Atlantic Seaboard and across Rhode Island and Massachusetts. The clue to this movement was found in the RAWIN observations from stations on the east coast of the United States, on 13 and 14 September which were reported to be south to south-southwest above 20,000 ft. Advance indications of the acceleration in velocity of the storm as it passed Hatteras was found in the strong velocities of the steering current north of 30° latitude. Streamlines for the 30,000-ft level on the 13th and 14th of October are shown in Figures 20 and 21.

Further evidence for the fact that mature hurricanes are steered at levels above the closed circulation was found in forecasting the movement of the Florida Hurricane of October, 1944. (Fig. 1, storm track number 11). Had the surface or 10,000-ft levels been used as a basis for determining the direction of movement of this hurricane before it began an almost due northward movement across Cuba and into the Florida Peninsula, the storm would have been forecast to pass southwestward or westward across the Yucatan Peninsula. This is shown by the 10,000-ft pressure chart at 0400Z on 17 October (Fig. 22), just after a gradual northward movement was first detected. At that time the tropical cyclone had attained full hurricane intensity and the circulation was known to extend above 17,000-ft. A pilot-balloon observation made at Swan Island at 161600Z, when the storm was about 100 miles northeast of that station, reported the winds aloft to be 300 degrees from the surface to 17,000 ft with velocities between 45 and 65 MPH throughout all levels. A clue to the wind flow above the storm circulation was given in the Orlando RAWIN observations made on 16, 17, and 18, October, as the storm approached that station. These reports are shown in TABLE 11.

Not until the storm came within 400 miles of Orlando at 1200Z, 18 October, could the winds at that station be considered to be representative of the steering current. However, the south and south-southwest winds at Orlando between 20,000 and 30,000 ft on the 16th and 17th showed 40 hours in advance that northward movement of the storm was probable. After 181200Z, the hurricane followed the steering current which was indicated by the 22,000 to 25,000-ft wind at Orlando.

The Atlantic and Florida Hurricanes of September and October were the only mature storms which entered the limited RAWIN network during 1944. High-level wind data obtained is still insufficient to prove conclusively that hurricanes are steered at the level above the closed circulation, However, the very satisfactory agreement between the stream line pattern in the high levels and the direction of movement of those hurricanes does, apparently, lead to a sound and workable basis forforecasting the movement of tropical cyclones.

Problems arising in the application of the steering principle to forecasting the movement of tropical cyclones are:- (1) determination of the steering level and (2) forecasting the changes in the direction and velocity of the winds at that level resulting in changes in the movement of the cyclone. No rigorous procedure has been developed for the determination of the steering level, but empirical rules, which can be applied with satisfactory results, have been devised and are given below.

(1) Tropical cyclones move with very nearly the same direction and velocity as the wind directly above the closed circulation.

(2) The approximate heights of the steering level of hurricanes in the various stages of evolution are:

(a) Formative: between 10,000 and 15,000 feet.
(b) Immature: between 15,000 and 25,000 feet.
(c) Mature: between 20,000 and 40,000 feet.
(d) Decaying: above 20,000 feet, but usually lower than that of the mature hurricane.

(3) Streamlines drawn for each 5,000-ft level up to 50,000 ft should be compared with the observed movement of the storm, giving special consideration to its stage of development. The level at which the air flow corresponds to the direction and velocity of movement of the cyclone is the steering level. Minor fluctuations amounting to plus or minus 5,000 ft may be observed in the steering level.

(4) When a formative or immature storm remains stationary 12 to 14 hours or more, the circulation builds up to higher altitudes which results in a higher steering level.

The 20,000-ft and 10-km pressure charts can be used to determine the orientation and changes occurring in the large scale pressure systems, which affect the steering current. When the steering level is between 20,000 ft and 10 km, it is necessary to interpolate between the two levels. The value of these charts is limited by the accuracy of pressure data above 10,000 ft and may be as much as 3 millibars in error. In the tropics, where pressure gradients are relatively weak, an error of 3 millibars is often sufficiently large to obscure important troughs and ridges. It is, therefore, necessary to make use of wind observations to the fullest extent in the analysis of all upper-level pressure charts. When winds are not available, however, upper-level pressure charts must be used to determine the steering current.

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TABLE II

RAWIN OBSERVATIONS AT ORLANDO, FLORIDA, FOR 16 TO 18 OCTOBER 1944

(Steering Current Indicated by Underscoring Reported Level)

	160900Z	161500Z	162100Z	170300Z	171500Z	172200Z	180600Z	180900Z	181200Z	181500Z	181900Z	182200Z
1,000 ft.	50° 21	70° 27	30° 30	30° 30	60° 26	50° 35	60° 30	70° 29	70° 38	70° 31	80° 36	70° 40
5,000 ft.	08° 32	60° 32	40° 42	60° 31	70° 29	80° 34	100° 30	90° 49	100° 32	90° 26	110° 46	110° 40
10,000 ft.	08° 14	90° 24	100° 05	90° 13	90° 17	80° 21	100° 29	130° 32	110° 28	100° 26	140° 37	130° 35
15,000 ft.	30° 05	130° 24	90° 04	10° 02	80° 06	100° 10	80° 16	120° 21	160° 20	130° 42	160° 42	150° 24
20,000 ft.	150° 13	140° 26	190° 20	260° 12	240° 22	210° 09	130° 26	170° 18	180° 35	150° 39	160° 35	130° 48
22,000 ft.	----	----	----	----	----	----	----	160° 23	170° 33	150° 44	180° 22	130° 48
25,000 ft.	160° 19	170° 22	230° 26	250° 35	210° 31	190° 30	200° 35	220° 34	180° 26	180° 30	190° 19	180° 27
30,000 ft.	210° 36	210° 48	220° 59	220° 50	240° 54	200° 42	210° 46	220° 46	200° 27	210° 54	180° 30	180° 33
35,000 ft.	230° 79	230° 60	230° 63	220° 70	260° 57	230° 64	220° 55	210° 64	210° 57	240° 46	230° 46	190° 40
40,000 ft.	----	----	240° 72	240° 71	260° 65	240° 65	250° 58	240° 52	220° 67	240° 35	----	220° 60
45,000 ft.	----	----	260° 66	----	----	250° 65	----	----	----	----	----	----
50,000 ft.	----	----	220° 52	----	----	----	----	----	----	----	----	----

RESTRICTED

RESTRICTED

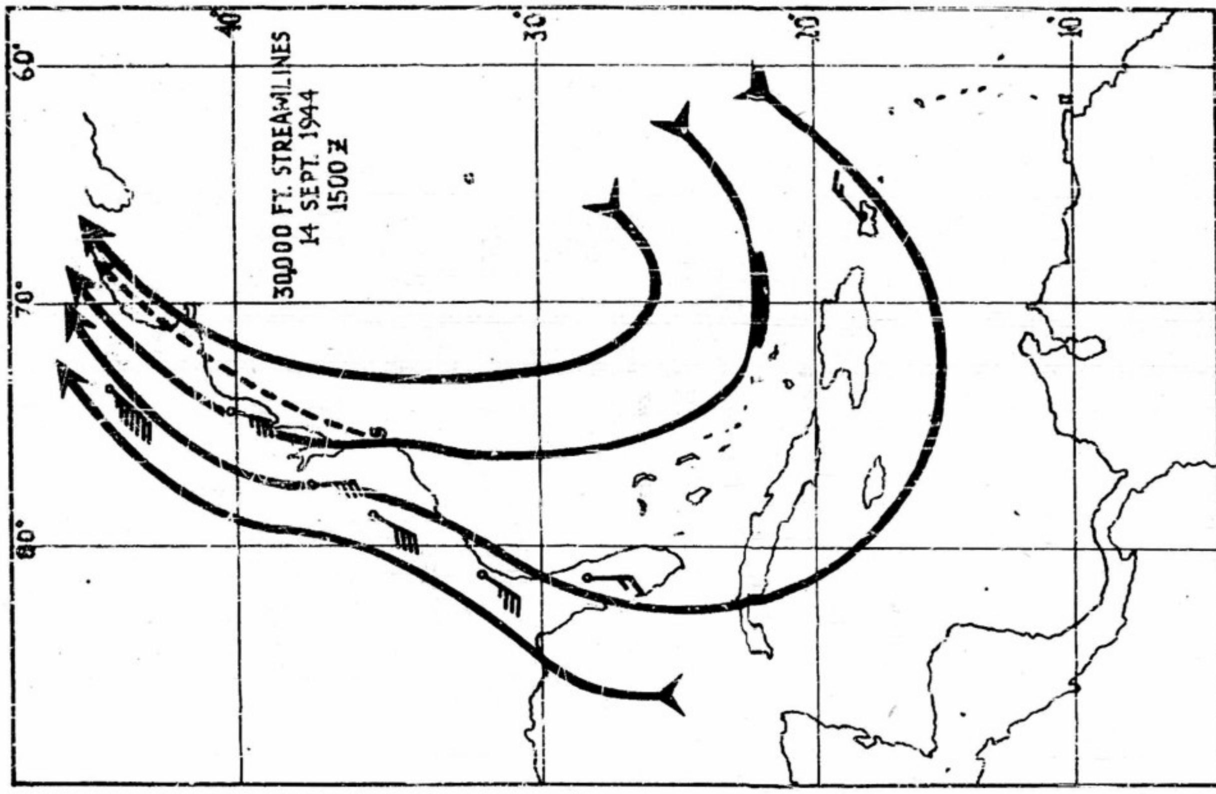
30,000 FT. STREAMLINES
14 SEPT. 1944
1500 Z
60°
70°
80°
40°
30°
20°
10°

FIG. 20

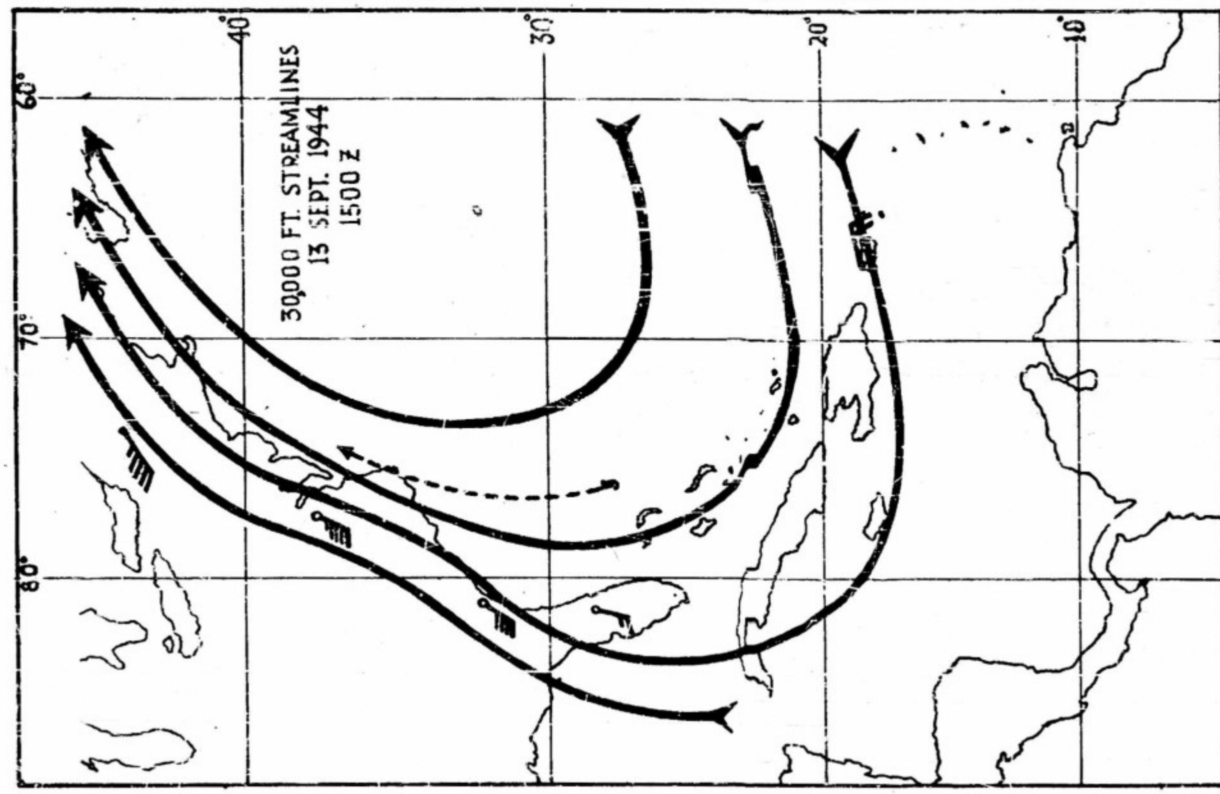
30,000 FT. STREAMLINES
13 SEPT. 1944
1500 Z
60°
70°
80°
40°
30°
20°
10°

FIG. 19

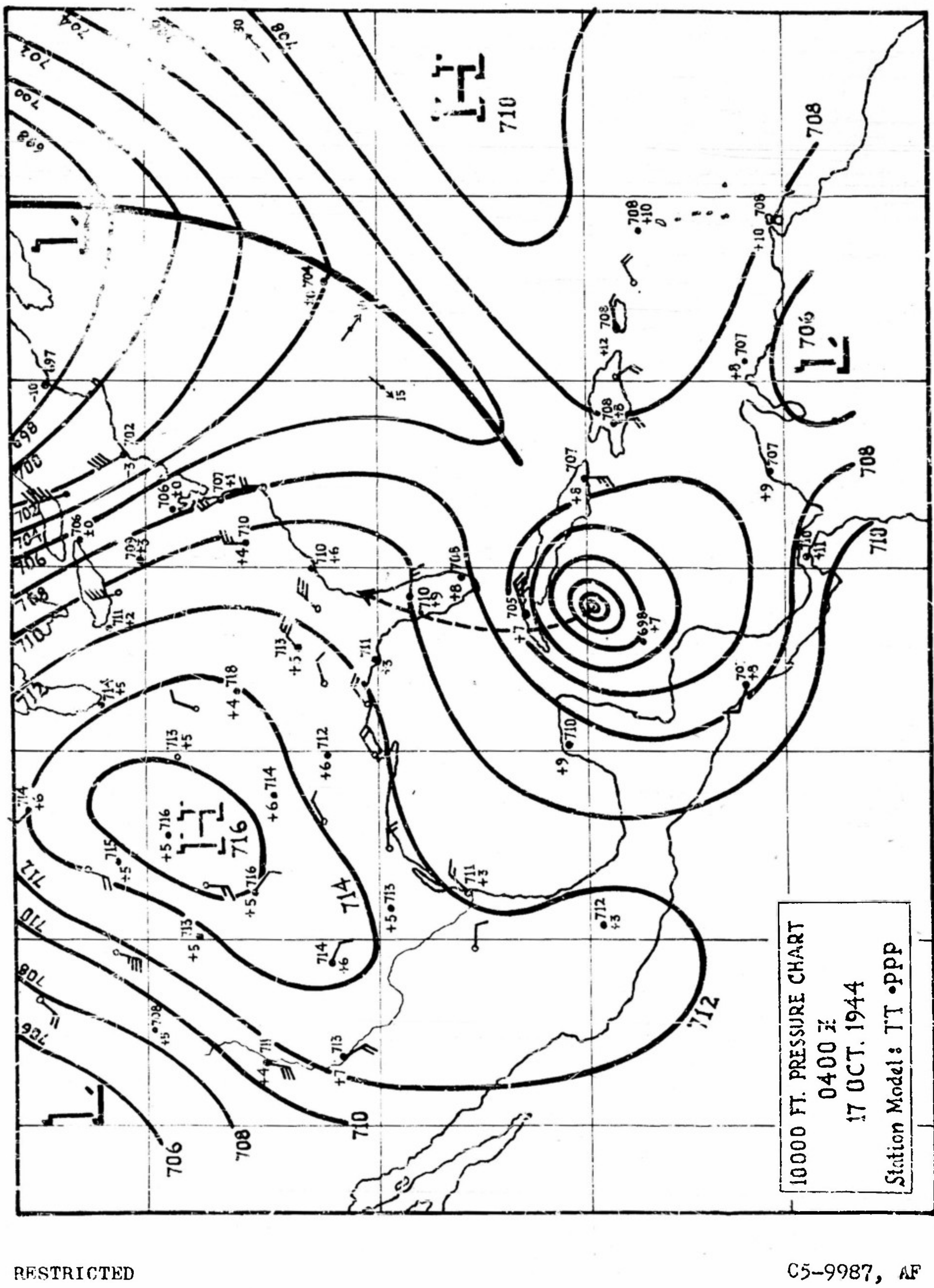
10000 FT. PRESSURE CHART
0400 Z
17 OCT. 1944
Station Model: TT •PPP

FIG. 21

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U.S. AIR FORCES, WEATHER DIV., WASH., D.C. (AIR WEATHER SERVICE TECHNICAL REPORT NO. 105-15)

ANALYSIS AND FORECASTING OF TROPICAL CYCLONES OF 1944 IN THE CARIBBEAN SEA AND WESTERN ATLANTIC OCEAN, WITH THE AID OF AIRCRAFT RECONNAISSANCE REPORTS AND RAWINS - FORMERLY WEATHER DIVISION REPORT NO. 962

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